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Transparency for Multi-Tier Sustainable Supply Chain Management: A Case Study of a Multi-tier Transparency Approach for SSCM in the Automotive Industry

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Abstract: Sustainability in supply chain management (SSCM) has become established in both academia and increasingly in practice. As stakeholders continue to require focal companies (FCs) to take more responsibility for their entire supply chains (SCs), this has led to the development of multi-tier SSCM (MT-SSCM). Much extant research has focused on simple supply chains from certain industries. Recently, a comprehensive traceability for sustainability (TfS) framework has been proposed, which outlines how companies could achieve MT-SSCM through traceability. Our research builds on this and responds to calls for cases from the automotive industry by abductively analysing a multi-tier supply chain (MT-SC) transparency case study. This research analyses a raw material SC that is particularly renowned for sustainability problems—the cobalt supply chain for electric vehicles—and finds that the extant literature has oversimplified the operationalisation of transparency in MT-SSCM. We compare the supply chain maps of the MT-SC before and after an auditing and mapping project to demonstrate the transparency achieved. Our findings identify challenges to the operationalisation of SC transparency and we outline how FCs might set to increase MT-SC transparency for sustainability.

Keywords: sustainable supply chain management (SSCM); supply chain transparency; multi-tier SSCM; sustainability; automotive industry; case study research

1. Introduction

The last decade has seen remarkable growth in the interest in sustainable supply chain management (SSCM). This entails how companies mitigate sustainability risks in their global supply chains (SCs), as well as how they improve their own sustainability performance by making their SCs more sustainable [1–10]. Continual advances in information and communications technology (ICT) have led to near-global connectivity. These advancements have not only made global sourcing and outsourcing [11,12] more practicable, it is also becoming easier for buyers and suppliers and sub-suppliers to pass on information [11,13]. On the other hand, critical stakeholders are more able than ever before to draw attention to the negative impacts of global firms' operations all around the globe [3,8,14–17]. At a time when consumers are increasingly wondering where and how their clothes are made and just how sustainable their potential new electric vehicle might be, given the raw materials required to make it, transparency in global supply chains is a core issue to be addressed. Just as Seuring and Beske [18] and Pagell and Shevkchenko [10] demonstrated the need for normalising sustainability

in supply chain management (SCM), in the last decade, authors have increasingly recognised the central importance of extending (S)SCM beyond dyadic supplier–buyer relations [19–23] to developing multi-tier SSCM (MT-SSCM) [24–30]. In order to achieve MT-SSCM, supply chain transparency is required in order to know which parties in the supply network must be engaged [14,23,25,31,32].

Whilst numerous authors have noted that some industries (such as food, agriculture, chemicals and pharmaceuticals) have been the subject of significant research on MT-SSCM [24,32,33], in which a degree of transparency has been/could be achieved, other industries such as apparel [24,34] and automotive [35–37] struggle to encompass the entire supply chain to achieve visibility and transparency. In this context, academics have drawn attention to the particular challenges and complexities of mineral SCs for MT-SSCM [38–41]. Such raw materials go through many processing steps that can include smelting and refining, often spanning multiple continents, making transparency and tracking/tracing very difficult [42]. Furthermore, whilst focal companies (FCs) are able to leverage their contracts with direct suppliers to demand conformity with sustainability requirements, the lack of a contractual relationship with sub-suppliers adds to these challenges. The challenge of multi-tier transparency in complex SCs, confronting both academia and practitioners [32,43,44], is, as Bastian and Zentes [32] refer to it, the 'key prerequisite' for achieving MT-SSCM.

Various authors have drawn attention to the serious sustainability challenges and risks in differing mineral supply chains [31,40,45–47]. The mining and extraction sector is an industry associated with invasive effects on the environment and hazardous working conditions [40,48–50]. Due to the many stages that some minerals go through before they reach the final consumer, traceability is a particularly difficult process [51,52]. One example of a raw material involving complex, opaque SCs is cobalt. Whilst the longest-standing focus has been on conflict minerals (tin, tantalum, tungsten and gold—the so-called "3TGs" [31,39,42,51,53]), cobalt has, for good reason, also received particular attention [54]. This attention has been directed to consumer electronics and increasingly to the automotive industry as significant downstream customers of lithium-ion batteries containing cobalt [16,55–61].

Sustained, targeted pressure on FCs related to cobalt follows a growing trend whereby companies are held accountable for negative sustainability impacts in their sub-supply chains [26,28,29,33,39,62], the so-called "chain liability effect" [15,63]. This pressure is becoming more acute because of the transition to electric mobility and a corresponding spike in demand for electric vehicle (EV) raw materials [36,54,58,60,64,65]. Although this recent activity could give the impression that the problems have only recently surfaced, knowledge on the importance of cobalt to the Congo and the precarious conditions and sever sustainability issues in the cobalt mining sector have been available for a long time (see, for example, Global Witness [66], Nordbrand and Bolme [67], Garrett and Mitchell [53], Franken et al. [49], and Garrett [68]). However, minerals SCs are simply indicative of a larger challenge facing academia and practitioners concerned with the implementation of MT-SSCM broadly across industries and product segments.

Garcia-Torres et al. (2019) point out that although traceability has been the focus of certain industries and achieved for certain products/produce, SC traceability for sustainability in general remains a distant reality. To address this gap in the literature, Garcia-Torres et al. [24] recently proposed a "traceability for sustainability (TfS)" framework, based on a comprehensive literature review of MT-SCM, SSCM, and apparel literature. The TfS framework outlines three dimensions, governance, collaboration and traceability and tracking, involved in an enabling cycle for more sustainability in multi-tier SCs [24]. Our research is motivated by a desire to apply this promising framework to a critical case to improve our understanding of how transparency can be achieved in MT-SCs for improved SC sustainability.

This case study research will attempt to answer the following research questions.

RQ1. *What challenges do focal companies face when operationalising transparency for multi-tier (sustainable) supply chain management, in particular opaque supply chains?*

RQ2. *How might these challenges be overcome and what are the implications for the TfS model?*

In answering these questions, this research aims to contribute to the research on how MT-SSCM is instigated, practised and improved. To achieve this, the current article expands on a part of the TfS framework proposed by Garcia-Torres et al. [24] and analyses how transparency can be achieved as a necessary pre-condition for traceability for sustainability in multi-tier supply chains (MT-SCs). Following a qualitative abductive logic, we begin with the TfS framework and undertake a case study of a project in which an FC sets to gain transparency in a cobalt supply chain. By providing learning from a particularly critical, complex and long supply chain, this article will demonstrate the challenges to realising MT-SC-transparency, contribute to a deepened understanding of how such a process can be operationalised in an MT-SC, in order to work towards the TfS envisioned by Garcia-Torres et al. [24]. Our qualitative research seeks to understand how the framework might look when applied in detail to a concrete case (a project to attain MT-SC transparency), thus our choice of a case study research approach (Eisenhardt, 1989; 1991).

The article continues with a review of the extant literature on SSCM, MT-SSCM, and transparency/traceability in the supply chain context, leading to the recently proposed framework for achieving MT-SSCM: Traceability for Sustainability [24]. Building on arguments presented in the literature review, the authors propose to deviate slightly from the term traceability (preferred as the overarching category by Garcia-Torres et al.), suggesting that transparency for sustainability is the optimal concept. After introducing the adjusted theoretical frame, the article describes the abductive qualitative research approach and the case study methodology. This is followed by the findings of the case study. Finally, in the discussion, identified challenges to TfS in MT-SSCM are presented, conclusions are drawn from the case and the authors propose ways for FCs to better achieve transparency for MT-SSCM. The article concludes with limitations to the research and makes recommendations for practitioners and academia for the further understanding of TfS and MT-SSCM.

2. Background

Responding to the opportunities presented by globalisation and in an effort to become more competitive, global companies have been profiting from globally dispersed supplier networks for a number of decades [12,69–73]. Recurrently and increasingly, various stakeholders have directed their critical attention to the negative effects of large FCs' sourcing and procurement practices and the perception of their responsibility for sustainability problems in their global SCs [8,21,23,35,74–77]. Thus, in hindsightKlicken oder tippen Sie hier, um Text einzugeben., it is not surprising that SCM expanded its focus to include sustainability and that sustainable supply chain management (SSCM) has become a prominent academic field in part responding to the calls for more critical attention [1,2,4,18,78].

2.1. Sustainability in Supply Chain Management Beyond Tier 1

Throughout the development of SSCM, many authors have focused on the barriers and drivers for implementing SSCM [3,9,29,79–81]. By early 2019, over 1500 drivers of SSCM have been identified [78]. However, one major barrier confronting FCs wanting to improve the sustainability of their SCs is the lack of SC visibility [31], hence limiting their ability to influence and improve sustainability in their sub-supply chains [15,29,73]. This corresponds to the earlier problem of SSCM research that focused on dyadic supplier–buyer relationships [19,22], whereby FC influence on sub-supply chain sustainability performance decreases with rising SC distance [22,28,29,82]. This initial dyadic focus in SSCM research is particularly interesting, given that seminal SSCM definitions include the entire supply chain [8,52]. Sauer and Seuring [28] argue that suppliers' and sub-suppliers' actions and practices are more likely to be adapted to their SC setting, rather than an FC's sustainability requirements, given the decreasing FC influence upstream in the SC.

To overcome the limited, prevailing dyadic SC focus, Mena et al. [22] conducted a multiple-case study of businesses from the food sector to propose a theory of multi-tier SCM and determined specific relational practices among SC partner in MT-SCs. The authors concluded that "more companies [will be] forging relationships across supply networks for various reasons, such as sustainability" and

recommended that future research examine multi-tier SCs "in other industries with more complex and longer supply chains, such as automotive or electronics" [22]. Seeking to advance this initial MT-SC research, Tachizawa and Wong [29] conducted a structured literature review and sought to advance this initial research by moving beyond relational factors in MT-SCs to governance mechanisms, practices and contingency factors. Importantly, they added the context of sustainability, creating multi-tier SSCM (MT-**S**SCM). Hartmann and Moeller identified and clarified a primary motivator for FCs to commence MT-SSCM and found evidence for the "chain liability effect" in MT-SCs [15]. Although they recognised the "limited" possibilities for FCs to establish full SC transparency, they noted, nonetheless, that "the market will punish the focal firm [FC] for its suppliers' behaviour . . . " and they recommended that "companies should work to ensure sustainable behaviour throughout the supply chain, to protect themselves from chain liability" [15]. They concluded by calling for additional research on how SCM can extend its reach to increase transparency in MT-SCs.

Grimm et al. [25,26] furthered MT-(S)SCM knowledge by focusing on the role of sub-suppliers and their interaction with FC sustainability requirements. They analysed two MT-SCs in the food industry and identified four groups of critical success factors that influence how successfully sub-suppliers will comply with sustainability standards [25]. They noted the need to obtain more data and conduct research in other industries/sectors. Building on these preceding contributions to MT-SSCM, Wilhelm et al. [33] identified the "instrumental" role of Tier-1 suppliers that have a double agency: fulfilling FCs' requirements and actively passing on such requirements to the upstream SC [33]. Their research involved FCs from the food industry and one consumer electronics FC. They concluded that their analysis demonstrates different applications of purchasing power, but that power asymmetries in SCs differ from industry to industry and that problems of (sub-)supplier opportunism can be "alleviated through increased efforts to improve supply chain transparency" [33]. In another study, based on data from seven MT-SCs in the food, apparel, packaging and consumer electronics industries, Wilhelm et al. [30] built on the FC practices identified and proposed by Tachizawa and Wong: "direct", "indirect", "work with third parties" and "don't bother" [29]. In close alignment with previous research, they discerned four MT-SC scenarios from their seven cases: open, closed, third party and "don't bother", as well as three main factors influencing FCs choice to conduct MT-SSCM: supply chain complexity, SSCM capabilities of Tier-1 suppliers and TBL/sustainability aspect in focus [30]. They recognised that different MT-(S)SCM contingencies may be present in different industries such as mining and automotive [30].

Drawing on their research into complex mineral SCs [40,41] and previous MT-SSCM frameworks, Sauer and Seuring [28] proposed a three-dimensional framework for MT-SSCM in which the sub-supplier's direct environment is taken into consideration and proposed strategies for improving MT-SSCM depending on various contingencies. In other research [41], Sauer and Seuring focused on the specific SSCM issues in mineral SCs and added to previous approaches for conducting MT-SSCM [22,25,29,33] by proposing a further strategy: the cascaded approach, whereby FCs collaborate with mid-SC actors, who act as a sort of second FC to drive sustainability requirements into the upstream SC. Due to the enormous complexity (involving hundreds and thousands of mid-tier suppliers) downstream FCs have been found to "jump the chain" [51] to engage with key upstream sub-suppliers/chokepoints and extend beyond their "visibility boundary" [31].

The primary problem that becomes apparent for companies trying to engage in MT-SSCM is knowing who their sub-suppliers are, where the raw materials originate and the sustainability conditions throughout the SC [83]. At present, the ability to trace raw materials for MT-SSCM and have total SC visibility is a utopia [24,43]. While academic and theoretical progress has been made on MT-SSCM, what is often missing is the recognition that SC transparency is a key pre-requisite before MT-SSCM can occur [32]. As Wilhelm et al. stated, managing the sustainability of sub-suppliers "is still the exception, rather than the rule" [30]. Gong and Jia et al. focused on how FCs can orchestrate their resources to achieve sustainability knowledge transfer through an MT-SC [84]. Importantly, in their case study, they transcended the triad with findings across and up to six SC tiers. They also recognised the

role that supply chain mapping must play as a first step in MT-SSCM activities. Assuming that achieving transparency (and the resulting SC visibility) is the key factor for MT-SSCM [31,32,41,82,85,86], it is apparent that FCs find it exceptionally difficult to achieve transparency in their MT-SCs [87,88].

2.2. Transparency in Sustainable Supply Chain Management

The need for transparency in supply chains has been the focus of numerous authors [14,31,34,43, 87,88]. In some industries, such as food, agriculture and consumables, supply chain transparency has received a lot of attention and made progress [3,25,32,73]. Garcia-Torres et al. [24,89] responded to the challenges outlined above by conducting a systematic literature review of SSCM and traceability, with a focus on the apparel industry as an industry demonstrative of acute sustainability issues and characterised by MT-SC transparency challenges. They proposed an ambitious framework, the enabling cycle "traceability for sustainability—TfS" that explains how FCs implement TfS to increase transparency for improved sustainability in MT-SCs. Their framework builds on previous theoretical models and proposes three main dimensions that explain the occurrence of TfS: Governance, collaboration and tracking and tracing [24], as reproduced in Figure 1 below. Garcia-Torres et al. conceive of traceability as a meta-capability that can have self-reinforcing positive effects on MT-SSCM. Hence, they posit that TfS is applicable to SSCM in all industries and may be able to positively disrupt existing SSCM and encourage more truly sustainable SCs [24].

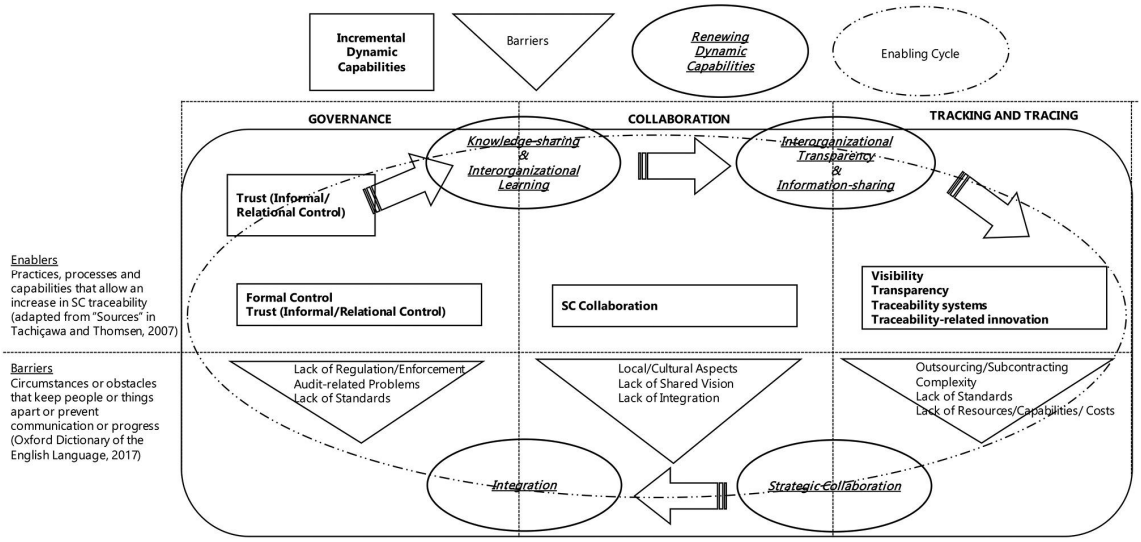

Figure 1. TfS cycle as proposed by Garcia-Torres et al. [24], reproduced with author's consent.

However, what is supply chain transparency? Trienekens and Wognum et al. define it as the extent to which all SC stakeholders share a common understanding of, and have common access to, product-related information that they request, without loss, noise, delay and distortion [73]. Hence the onus is on the stakeholder (whether FC, supplier, or parties affected by SC activities) to request transparency. Egel-Zandén et al. note that transparency expectations on FCs have extended into their supply chains, leading to the ascension of the concept "supply chain transparency", which they define as the "disclosure of information about supplier names, sustainability conditions at suppliers, and buyers purchasing practices" [43]. The OECD explicitly recommends that downstream companies implement a "supply chain transparency system" that enables the identification of key midstream SC actors and thereby countries of origin of all raw materials [86]. Some critical authors point out the potential for and documented misappropriation and abuse of purported supply chain transparency [45,87,88]. Notwithstanding, this research follows Gardner et al. in their neutral assessment of the term, namely that supply chain transparency alone is "neither inherently good, nor bad and that the impact of increased transparency depends . . . on *what information* is being made transparent, *how*, to *whom*, and

for *what purpose*" [38]. Furthermore, they highlight that transparency can "demystify" highly complex SCs, allowing risks to be identified and targeted improvements to be made [38]. Thus, in alignment with the logic of Garcia-Torres et al. [24], we argue that transparency in MT-SCs should not just be transparency for transparency's sake, but rather must be *transparency* for sustainability (TfS).

2.3. Differentiating between Supply Chain Traceability and Transparency

Garcia-Torres et al. [24] make a compelling case for focusing on traceability as the defining activity (the "doer") in their framework for improving SSCM's reach in complex MT-SCs. Still, as Young and Dias [42] clearly portray, it is important to understand the nuances and differences between tracking and tracing in MT-SSCM. Traceability is certainly a common transparency approach for FCs (see Figure 2) that aim to achieve more transparency in their upstream SCs, by tracing back "up" the supply chain to determine the origins of their products. Gardner et al. [38] build on the SC transparency framework of Egels-Zandén et al. [43] by proposing that SC-transparency consists of six types of information: traceability, transaction, impact, policy and commitment, activity, and effectiveness information [38]. This underlines our argument that traceability is a key measure that contributes to the *overarching concept* of SC transparency. Hence, we concur that traceability is one of a number of steps/approaches to achieving transparency for sustainability in MT-SSCM. Also, practically speaking, transparency is an indisputable precondition for undertaking traceability—an FC must know who it should interact with ("who is my Tier 2?") before it can begin tracing its products or raw materials up the SC. Depending on who is instigating MT-SC transparency (i.e., focal companies, raw materials producers, mid-stream players such as refineries and smelters, or third party actors), there will be different approaches to gain transparency for sustainability (see Figure 2). Material or product tracking is most relevant for upstream SC actors (such as raw material producers) or FCs that know the source of their materials and who want to "track" the supply routes that the materials/products take, down the supply chain. By contrast, traceability is the approach for SC stakeholders to uncover the origins of a product or raw material by retracing the route taken up the supply chain. Mid-stream SC members would employ both approaches to gain full SC transparency.

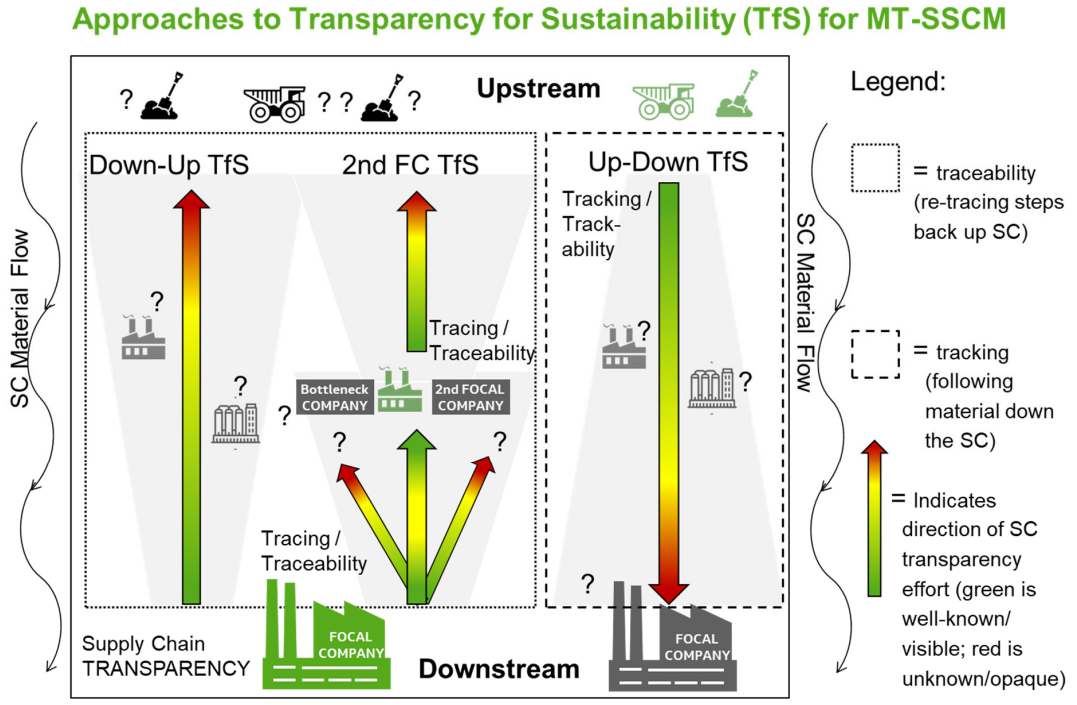

Figure 2. Different approaches to SC transparency (visibility, tracing and tracking)—authors' depiction, loosely based on Young and Dias [42].

In conclusion, we generally adopt the TfS framework [24]; however we substitute the term traceability with transparency in the title, thus rebranding the model "*Transparency* for Sustainability". Garcia-Torres et al. [24] actually propose that "visibility and transparency are preconditions for effective tracking" and suggest a four-step process: (1) Integration of visibility (access to / share information); (2) Transparency becomes core element—as a practice; (3) Integration of traceability systems; and (4) Traceability related innovation—extend transparency from SC actors to non-SC actors. Thus far MT-SSCM research has been primarily focused on the food and somewhat on the chemical and pharmaceutical industries. Although the TfS [24] framework is based on an analysis of the apparel industry, it has the potential to be applied generally, independent of a specific industry. Many other MT-SSCM frameworks imply knowledge about the necessary SC triads/sub-supply chain structure [22,25,26,29,30] or treat it as an unknown field (e.g., "Tier-n space" [28]) requiring supply chain mapping for SC sustainability learning [84] or coalition with key SC chokepoint actors to cascade requirements and extend FC reach [41]. The TfS model recognises the central necessity for the discovery of the MT-SC (traceability/transparency) and frames this on the same level as SC collaboration and SC governance. Hence, our abductive research sought a challenging, qualitative case study to further analyse the potential workings of this framework. We particularly focus on the crucial part (highlighted in Figure 3) of their TfS framework in our in-depth case study. The research contributes to moving beyond a theoretical proposition of processes, interdependencies, antecedents, drivers and barriers, to understanding how entities can operationalise transparency for sustainability in their SCs, to suggest how transparency for sustainability can be achieved in MT-SSCM.

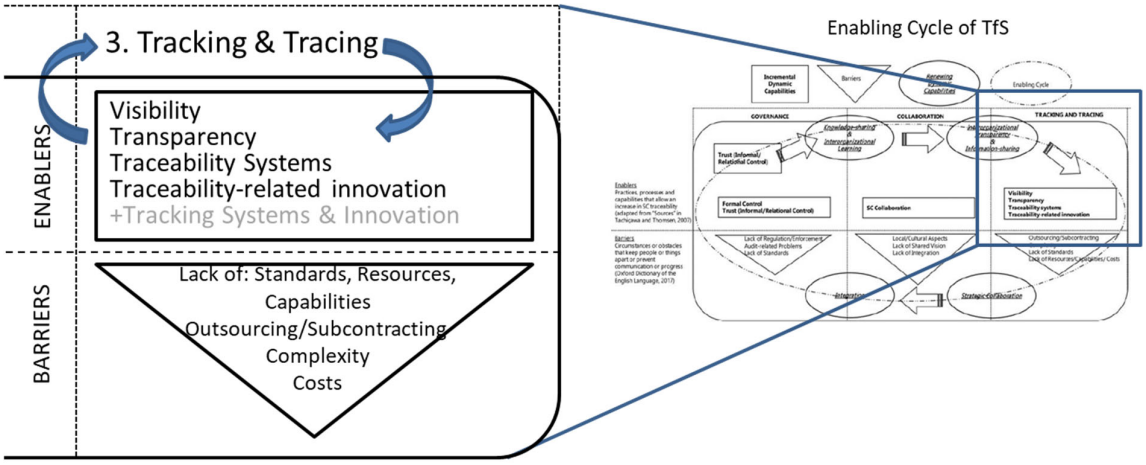

Figure 3. Research focus: tracking and tracing dimension of TfS cycle (reproduced with the explicit consent of the corresponding author) [24]..

3. Methods

Noting the calls from the literature for a more in-depth understanding of how SC transparency can be achieved, this research employs a qualitative, abductive research design [90–93]. This is because abductive analysis research "specifically aims at generating novel theoretical insights that reframe empirical findings in contrast to existing theories" [93]. With a grounding in the extant MT-SSCM literature summarised in Section 2 above, we discovered and gained access to a potentially interesting case of a project attempting to attain MT-SC transparency. We qualitatively analysed this case, suspecting to encounter "surprising empirical findings" in order to return to the pre-conceptualisations we had formed based on our review of the literature. Once the case study was underway, we returned to the literature, in an iterative sense to inform our analysis of the qualitative findings [93–95]. In such a manner, abductive research seeks to supplement or improve existing research and theory, with findings obtained from empirical idiosyncrasies [96–98]. The TfS-enabling cycle framework seemed promising but optimistic when imagining its application to an opaque, high-risk SC, such as the cobalt

SC in the automotive industry. Bitekine argues that research should not only explore "quantifiable aspects of … process explained by theory but also those … aspects … that cannot be adequately quantified" [99]. For this case study, the researchers gained access to a project, in which a global focal company, hitherto "FC1" (referred to as FC1 to distinguish it from the common abbreviation FC/FCs for any/all focal companies), and one of its suppliers attempted to obtain MT-SC transparency for sustainability purposes (such as to gain visibility, capture sustainable procurement practices, evaluate OECD due diligence compliance) in a complex cobalt SC. The selected mineral supply chain demonstrates characteristics [41] that set it apart from many of the previous supply chains (e.g., food, precious stones, pharmaceuticals, and apparel) that had served as the cases upon which previous frameworks and theories of MT-SSCM have thus far been based.

3.1. Case Study Research Design: Single Case—Within Case Analysis

Due to the need for empirical examination of the TfS framework [24,89], we employ a case study research approach, to make participant observations [100] about the "real world phenomenon" [101] and process [102] of multi-tier SSCM. This research attempts to understand TfS in a case-context and to what extent the empirical findings correspond to the theory discussed in Section 2.2 above [103,104]. Cavaye points out that while there is a tendency towards positivism and deductive approaches among proponents of case study research (see, for example, Lee [105], Orlikowski and Baroudi [106], and Yin [100,104]) case study research may entail an unstructured, interpretive investigation of a single case [103]. Whilst numerous authors underline the importance of multi-case case study research, particularly for validating concepts [104,105,107,108], others point to the value and necessity of single-case case-study research [100,103,109,110].

As Eisenhardt explains, case studies can be useful for generating important new insights, particularly those concerning under-researched phenomena, where "current perspectives seem inadequate because they have little empirical substantiation" [108]. Cavaye [103] adds that the purpose of a single-case study can allow the researcher to understand the nuances of a phenomenon in depth. Previous research had called for an examination of the automotive industry for MT-SSCM and transparency [22,24,30,33]. With access to an illustrative FC project in the automotive industry, we decided on a single-case case study, employing within-case analysis. For this case study, the unit of analysis is the cobalt supply chain under examination.

3.2. Case Selection & Definition, Case Study Actors

Our case study concerned the SSCM of the automotive company "FC1" and specifically the SC mapping and auditing work of an auditing and supply chain specialist consultancy "ASPC1", undertaken on behalf of FC1 and one of their strategic Tier-1 suppliers (hitherto "T1S") on their common cobalt SC. Increasing climate and environmental pressure, driving the ramp-up of electric vehicle production on the one hand, coupled with the shocking conditions presented in the media around cobalt mining on the other, make the cobalt supply chain a pressing candidate for SSCM research. Add to this, the particular brand and purchasing power of automotive OEMs to require more transparency in their SCs makes an automotive OEM an ideal candidate to be selected for an in-depth MT-SC transparency case study. In this case, SC transparency was understood to include finding out if the supposed knowledge about the sub-SC was extensive and complete and to determine the capacity of sub-suppliers at each stage for contributing to and achieving SC transparency as well as responsible sourcing, due diligence and other sustainability practices. However, the establishment of MT-SC transparency, in the sense of visibility of the sub-supplier ecosystem, remained the focus of this research, as we consider it to be the prerequisite for further sustainability/SSCM activities.

The initial project that constitutes the case ran for six months. In order to map the common supply chain of FC1 and T1S for upcoming models (start of production in the following year), ASPC1 implemented its due diligence and supply chain mapping audits methodology for cobalt on the respective FC1 cobalt SC. Supply chain mapping audits go beyond a typical supplier audit. They not

only focus on the supplier and the conditions and capabilities at the supplier's direct facility but also entail an explicit focus on the supplier's position in the supply chain and to uncover the supplier's supply sources and validate this information (see [111] for more information). In Section 4, we outline the background and setting of the case study, as well as providing a description how transparency was achieved through SC mapping audits.

3.3. Data Collection

Our research involved thorough observation and analysis of a single channel of data generated through the implementation of ASPC1's proprietary methodologies, which comprised multiple forms of qualitative data [100]. These included supply chain maps, audit responses, risk analyses, audit reports, researcher participant observation and project correspondences. ASPC1 was contracted by the multi-national automotive FC (herein referred to as FC1) and one of FC1's Tier-1 suppliers (T1S) to apply its methodology to the SC in question. The initial cobalt supply chain map was provided to FC1 and ASPC1 by T1S concerning the cobalt supply chain for relevant upcoming products based on T1S's MT-SC knowledge and what they were able and willing to provide at that point in time. This depiction of the MT-SC (see Figure 4) was taken as the baseline data, against which real and verified SC data was collected by ASPC1 and compared. Based on the original mapping, audits assessing the capacity for MT-SC due diligence were planned with ASPC1. One of the researchers participated in biweekly project calls, had access to project documents and correspondence, analysed ASPC1's audit reports and contributed to brainstorming about how to improve project processes.

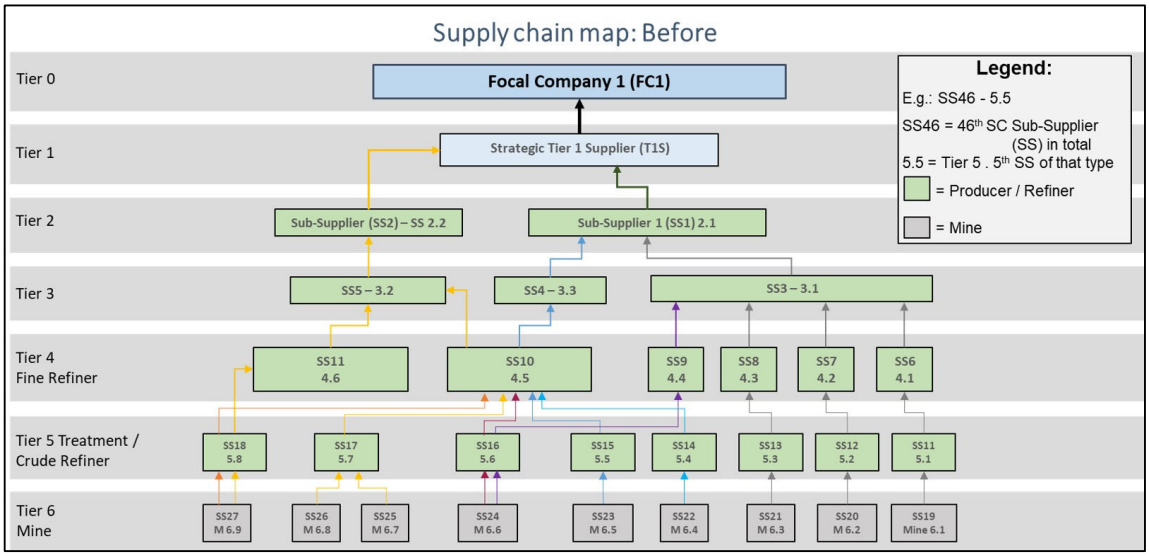

Figure 4. Initial map provided to FC1 by TS1 of FC1's cobalt supply chain.

3.4. Analysis

Our abductive research involved reviewing how MT-SC transparency has been understood in the literature and what approaches have been proposed. We then turned to our specific case to analyse "how" transparency for sustainability was operationalised in MT-SSCM from an FC's perspective. Hence, we set out to capture and then compare the MT-SC transparency knowledge (data) that a focal company could obtain by simply asking its Tier-1 supplier, with the transparency data gained by conducting SC mapping audits and due diligence/sustainability assessments using ASPC1's SC audit and mapping methodology. Based on the SC data, which ASPC1 enabled and uncovered for FC1 and T1S in the project, we identified and compared the disclosed/known number of SC (sub-)suppliers, to demonstrate how an FC's SC-transparency may be quantified and operationalised. Beyond this quantified data, we made observations about real-world processes, barriers and enablers that can affect

aspects of MT-SSCM, such as tracking and tracing, governance and collaboration, with reference to the TfS framework. Our particular analytical focus was on the implementation process, to identify what steps precluded what results, in order to demonstrate how to make progress towards MT-SC transparency. In our analysis of the data generated by ASPC1 for FC1 and T1S, we aimed to further operationalise the TfS framework and identify additional factors that may be necessary for the proposed TfS enabling cycle to work.

4. Case Study

4.1. Setting & Project Background

As part of its SSCM strategy, FC1 is focussing on SC-transparency as a precondition for other sustainability activities in critical sub-supply chains. FC1, like numerous other focal companies that have cobalt in their final products, recognised the significant risks associated with the raw material. Critical stakeholders have increased pressure on global brands to improve their SC due diligence and address issues associated with cobalt supply. However, as FC1 did not source the raw material directly, the challenge was to improve transparency and find out where the cobalt in various parts and products came from. Thus, risk management was a driver for obtaining more transparency in such a high-risk SC. FC1 engaged in industry-wide discussions and followed the newest developments in cross-industry forums. There were various previous attempts to ascertain information about the sub-supply chain, including a pilot project involving a cobalt-specific questionnaire that was to be "cascaded" down the supply chain. Whilst this pilot made some progress (down to Tier 3 and 4 in a few instances), it was generally recognised that the methodology was not sufficient and relied heavily on the goodwill and honesty, as well as the capacity and knowledge, of suppliers about the structure of the sub-supply chain. Since 2016, FC1 had decided to engage in direct dialogue with strategic future suppliers of cobalt-containing products and carry out sustainability workshops in order to identify common areas of focus and risk and then to determine the next steps to address the identified risks.

One of the companies FC1 engaged in such a sustainability workshop was a strategic supplier, T1S. As part of this engagement, the need for more transparency in T1S's supply chains for FC1's products was determined. The culmination of several supplier sustainability engagement workshops between T1S and FC1 was an agreement to jointly commission ASPC1 to map and conduct supply chain mapping audits of the common cobalt supply chain for upcoming products.

4.2. Cobalt Supply Chain Mapping Project for Multi-Tier Supply Chain Transparency

Our research team had access to the planning, execution and results of a supply chain mapping and auditing project, implemented by ASPC1 for FC1 and T1S. The scope of the project was focused on establishing T1S' multi-tiered supplier ecosystem (the complete picture of the sub-supply chain, including all supply chain partners) for cobalt material in FC1's products down to the mine level. This case study includes a description of the background, motivations and setting leading to such a supply chain transparency project, and the importance of the access to ASPC1's audit methodology to achieve the goal of the project. It also offers a description of the process of how transparency in this specific case was conceived, how the project was implemented, and to conclude, a comparison of the supply chain maps, before and after the project had been completed (representing the transparency achieved).

Supply chain mapping audits entail auditing a supplier to gain an exhaustive picture of the supplier's sources for the product concerned, in this case, cobalt. ASPC1 was selected by FC1 and T1S due to its successful implementation of supply chain mapping audits globally for other companies and the required expertise to complete the project. Both commissioning companies' management agreed to carry the cost of auditing sub-suppliers. This entailed the possibility of opening up the sub-supply chain and potentially being made aware of and exposed to more unknown risks. However, given the increasing (critical) interest in electric vehicles and the requirement that they be produced more sustainably, coupled with FC1's general increased emphasis on sustainability in procurement,

both companies decided to undertake the project. Following the co-ownership logic of the project and tri-partite implementation, and recognising that risks in the cobalt supply chain would affect both FC1 and T1S, the companies agreed to co-fund and manage the project. Moreover, as a direct supplier of FC1, T1S also reported that it saw participation in such a project as part of demonstrating a commitment to FC1's supplier requirements that they were motivated to fulfill.

To begin the mapping and auditing process, T1S provided FC1 and ASPC1 with an initial SC map, outlining T1S's understanding and knowledge about the cobalt SC, as far as it related to FC1's products. This "before" map was based on information provided to T1S by its suppliers and sub-suppliers. This initial map revealed the following initial, presumed MT-SC situation (see Figure 4).

According to the original SC map estimate, the SC involved the following sub-supplier levels: Tier 2—two cathode producers; Tier 3—three pre-cursor material producers; Tier 4—six fine refiners; Tier 5—eight crude refiners/treatment units; and at Tier 6—nine mines (see Figure 4).

4.3. SC Mapping, Auditing and Project Processes

The scope of this initial project was decided based on the information regarding the SC structure and the number of sub-suppliers provided in the initial map to FC1 by T1S (recall Figure 4). Based on ASPC1's advisory, it was agreed to begin auditing and mapping the supply chain tier by tier. At all tiers in the supply chain, ASPC1 checked the relevant company's due diligence in sourcing, managerial awareness and responsibilities, and their due diligence system and site/company sustainability performance. They then proceeded upstream up the SC. The case data was primarily generated through the process of auditing sub-suppliers. The SC mapping audits followed a general supplier audit process for engagement, communication, execution and follow-up, as depicted in Figure 5.

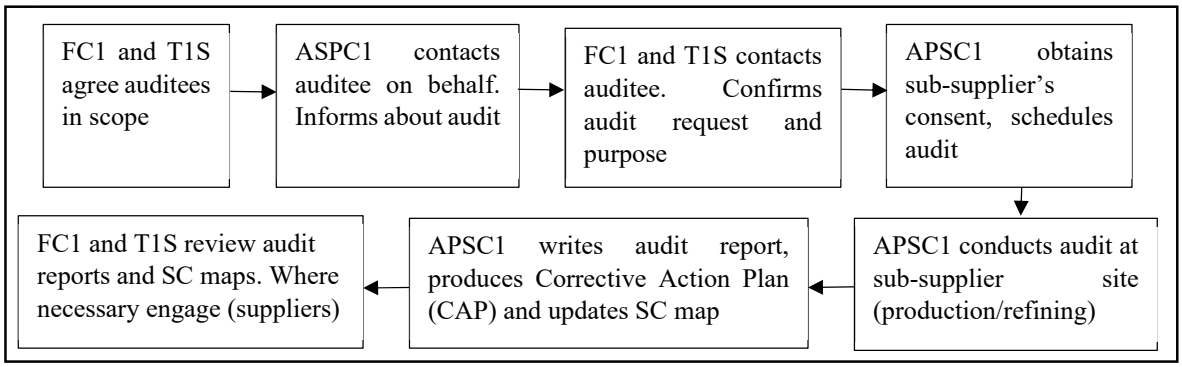

Figure 5. Supply chain auditing and mapping process.

The SC-mapping audits were announced and requested by ASPC1, explaining that the audit had been commissioned by FC1 and T1S. Follow up communication by FC1 and T1S was occasionally required to secure sub-supplier acceptance and participation. Each audit generated numerous types of data: process data; SC-mapping data (sub-supplier determination); general supplier sustainability performance data; and particularly, supply chain due diligence data (supplier practices and information measured against OECD guidance, 86). ASPC1 conducted the audits onsite at each of the concerned (sub-) suppliers' facilities, which included documentary and records reviews, management and employee interviews and a facility walk-through for observation. Beyond the supplier data, SC map updates, audit reports and correspondence, the corresponding author also made observations and gathered experience regarding the processes, communication and collaboration, involved in such an MT-SC transparency undertaking.

ASPC1 agreed to provide regularly updated SC maps together with audit reports to demonstrate progress made to T1S and FC1. Regular bi-weekly calls were held between FC1, T1S and ASPC1 in order to discuss progress, escalate issues, brainstorm communications for encouraging sub-supplier participation and acceptance of the audits, request and follow up on corrective action plans, and

begin responding to identified risks and issues. FC1, T1S and ASPC1 allowed one of the researchers to accompany an audit of one of T1S's plants, allowing the authors to gain an understanding of how such an SC mapping and due diligence audit is carried out in practice. By the end of an audit, the (sub-)supplier must prove to ASPC1 that they are able to exercise due diligence on the materials under scrutiny in their SC. FC1 decided to continue the SC transparency project in phase two, involving an extension of the auditing and mapping activities to cover discovered but not yet audited parts of the supply chain.

5. Case Study Findings and Analysis

In this section, we begin by describing the primary transparency findings of the MT-SC mapping project that constituted our case study, and then we present the findings of this project organised into abductively determined categories.

5.1. Case Study Findings

Our qualitative case study of ASPC1's SC mapping and auditing methodology, implemented in FC1's and T1S's common SC, provided us with a rich picture of the complexity, challenges and required steps for obtaining MT-SC transparency. The primary finding of the case study was that the cobalt supply chain, which constituted the unit of analysis of our research, was in fact far more complex than either FC1 or T1S had anticipated and revealed many unknown SC actors, particularly in the midstream SC, as shown in Figure 6. Sub-suppliers are marked green, traders blue and mines grey.

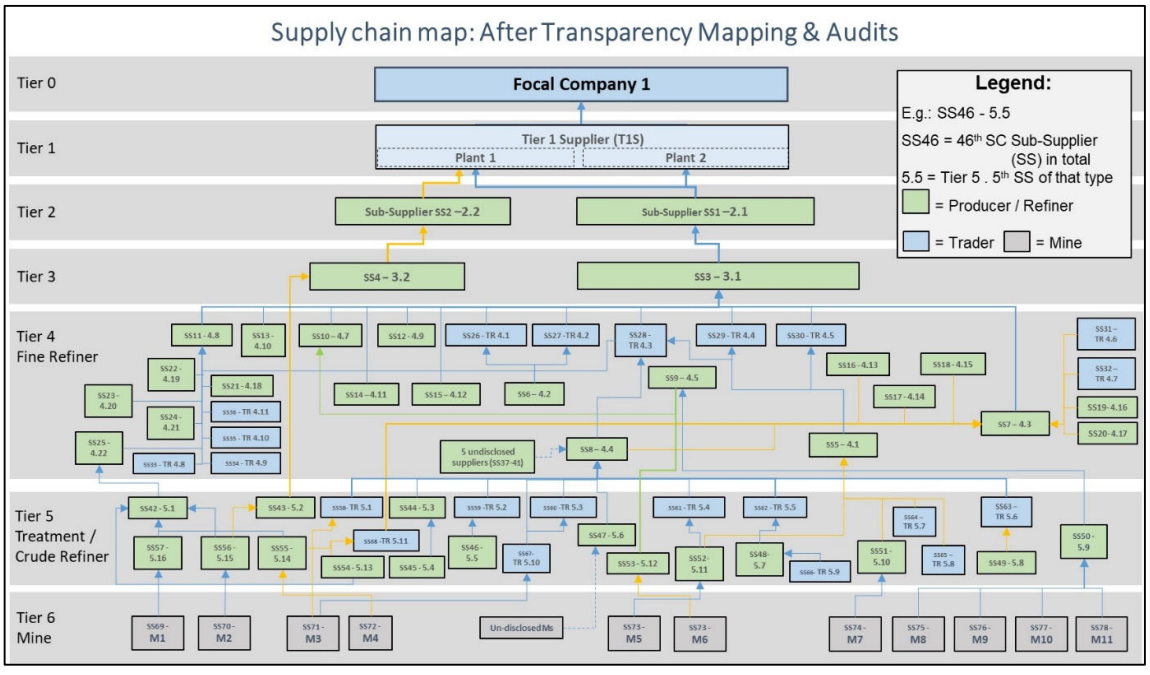

Figure 6. Updated supply chain map after the conclusion of Phase 1 of SC mapping and audits project.

A cursory comparison of the two SC maps (depicted in Figures 4 and 6) reveals that a clear and significant increase in MT-SC transparency was achieved and thereby a better understanding of the sub-supply chain. As portrayed in Table 1, the number of identified SC actors increased from 28 to at least 79, representing a 182% increase in visible, identified SC actors.

Table 1. Comparison of number of known/disclosed supply chain actors in FC1's cobalt SC.

Supply Chain Tier	# SC Actors Initially Identified	# SC Actors Identified After Project
2nd Tier—Cathode	2	2
3rd Tier—Pre-Cursor	3	2
4th Tier—Fine Refiner	6	37 (21 + 11 Traders + 5 undisclosed)
5th Tier—Crude Refiner	8	27 (16 + 11 Traders)
6th Tier—Mine	9	11 (+X? undisclosed)
Total	**28**	**79** (+ X?)

Having established these primary comparative findings, we continued with an abductive approach, iterating between the accumulated data, experiences, process knowledge and identified gaps learned in the project and the MT-SSCM literature. In so doing, we began to identify categories of issues to group our findings. These categories were as follows: unexpected sub-supply chain complexity (Section 5.1.1); distance of T1S to its upstream SC (Section 5.1.2); MT-SC collaboration and governance (Section 5.1.3); iterative nature of attempts to gain transparency in MT-SCs (Section 5.1.4); and finally, that transparency, once obtained, only represents a temporal snapshot of the MT-SC (Section 5.1.5).

5.1.1. Complexity of Analysed Multi-Tier Supply Chain

The project for improved transparency in the cobalt supply chain was enlightening for both FC1 and T1S. Already after just a handful of supply chain mapping audits, it became abundantly clear that the cobalt supply chain was much more complex than initially understood by both commissioning parties. The prior knowledge, existing methodology and practical implementation experience of the implementation partner, ASPC1, were crucial to the project. The regular SC map updates, provided by ASPC1, clearly demonstrated that the initial supply map provided by T1S was insufficient and incomplete. Not only were many new sub-suppliers uncovered, but the number of traders at various tier-levels added to the complexity, as traders entertain supply relations to many more other SC partners. Even after only a dozen SC mapping audits, the SC complexity became so intense, that it was proving difficult to visualise using standard office computer tools.

5.1.2. Distance of Tier 1 to Upstream Supply Chain

Partially owing to the complexity described above, like many Tier-1 suppliers, T1S is highly removed (6 tiers, not including middlemen functions/traders selling material within the same SC tier level) from the upstream SC (mining/extraction level). This case made it apparent that T1S was ill-informed about and/or ignorant of its own sub-supply chain. T1S's initial disclosure was dependent on information from their own direct suppliers. Hence, the case study was not only a wake-up call for T1S, it demonstrated to FC1 that their Tier-1 suppliers probably have decidedly limited transparency knowledge about their sub-supply chains. The project also helped T1S make the case to its management for more resources and organisational attention, in order to have a better picture about SC transparency in the future. The case demonstrated the pressing need to FC1 to engage its direct suppliers of critical raw materials in order to ensure that MT-SC transparency and due diligence would be improved.

5.1.3. Multi-Tier Supply Chain Collaboration & Governance for Sustainability

Once the project began, it also became clear how an attempt to increase transparency (and work towards traceability) also impacted SC collaboration and SSCM governance. Through the thorough work of ASPC1, particularly in the cobalt ecosystem, FC1 and T1S were conducting audits that aligned with global institutional expectations, such as OECD due diligence requirements and Responsible Minerals Initiative (RMI) and Responsible Cobalt Initiative (RCI) governance expectations. Although sub-suppliers accepted the audits, they pointed out that similar audits were being conducted

frequently by different global FCs and that there was a pressing need for more standardisation and alignment. Such considerations around the frequency of audits led to ASPC1 and FC1 deepening their relationship to engage other companies in collective action processes with the objective to reduce overall costs and time spent without losing robustness of MT due diligence process. The combined, collaborative approach of FC1, T1S and ASPC1 pushing for more transparency in complex supply chains was effective. The collaboration between the three parties resulted in a high up-take rate of sub-suppliers agreeing to the audits, with only one sub-supplier refusing the audit, reportedly due to audit fatigue. This sub-supplier instead offered to share their third-party audit results with T1S and FC1. With FC1, T1S and ASPC1 working together, the combined weight/clout seemed to have positive effects in terms of ensuring participation and SC disclosure. Not just in the sense of "pressuring" sub-suppliers to agree to audits, but also in terms of engaging with sub-suppliers on the broader issues of transparency, sustainability, instituting management systems for responsible sourcing/due diligence and MT-SC sustainability risk management. Although initial engagement of some sub-suppliers took some recurring effort, once contact had been established, opportunities for increased engagement and cooperation became possible. The direct engagement led to more MT-SSCM exchange, also among FC1 and its ier 3, 4, and 5 sub-suppliers. The transparency obtained served as a foundation, upon which both FC1 and T1S could base further MT-SSCM measures and activities.

5.1.4. Iterative Nature of Gaining Transparency in Multi-Tier Supply Chains

The initially contracted audits focused on those company types mentioned in the initial disclosure: pre-cursor and cathode producers as well as fine refiners and crude refiners, with a goal to find out the point of origin of raw materials (i.e., mine sources). Whilst the project led to making progress up the supply chain, it was also clear that more iterations would be necessary to uncover new "branches" in the mid-stream supply chain map. Both companies noted that attempts to trace the live material flows of raw material supplies from the origin through the SC (for example, with the help of blockchain technology) would be more fruitful when a comprehensive discovery and visibility of the majority of the supply chain has been achieved.

5.1.5. Temporal Nature of Supply Chain Mapping

The case study was based on a disclosed "SC snapshot" from a set point in time. APSC1 audited supplier relations over the 12 months prior to the audit. Even throughout the relatively short, 6-month project, there were proclaimed changes to sub-supply chain structures. This meant that planned future audits were rejected by Tier 4, as they claimed that they no longer sourced from particular identified Tier 5/Tier 6. This posed a challenge in terms of FC1's and T1S's risk management, as the emerging supply chain map was static whereas supplier relations are dynamic. Also, it is possible that sub-suppliers will cancel purchasing contracts for some time (e.g., due to reputational risk) and then resume the supplier relationship later. Or they can simply claim to have cancelled business relationships when in fact this is not the case. For these reasons APSC1 encourages FCs and customers to invest in longer-term, recurrent auditing programmes, to drive continuous improvement and to ensure that this improvement is tracked over time, allowing such SC changes to be monitored and validated.

5.2. Within Case Analysis

When surveying the academic literature on MT-SSCM, one could gain the impression that discovering and then interacting with the sub-supply chain is a rather straightforward undertaking. Garcia-Torres et al. [24] and other frameworks [22,28,29,33,41] appear to assume that knowledge about the other SC participants is available, accurate and exhaustive/complete. Or if it is not, that the information to be gained from direct suppliers about Tier 2 or key mid-stream sub-suppliers (such as smelters, refiners) is accurate. Our case study found that such assumptions would be ill-advised. Neither did the extant literature propose guidance on the "how-to" of achieving transparency/traceability. Even in the TfS framework, this seems to treated as self-explanatory. Our case study

findings shed light on an indicative process of how to achieve MT-SC transparency, and demonstrated that it can be a highly complex, demanding process, which may require significant resources and expertise (in this case, external expertise, such as that provided by ASPC1). Moreover, the process entails and requires extensive supplier coordination, cooperation and collaboration, which is neither a given nor self-explanatory. Obtaining transparency is resource-intensive and time-consuming (e.g., manpower, correspondence, activating multiple hierarchy levels within each company, contracting third-party experts). Such activities required attaining support and commitment from management in both participating companies, who aimed to achieve MT-SC transparency. However, once the process of supply chain mapping for transparency had begun, it led to a strengthening of the strategic partnership between FC1 and its supplier T1S as well as between both parties and ASPC1. This, in turn, helped to improve collaboration and communication with suppliers/sub-suppliers and eventually led to more trust among participating SC actors. This trust and collaboration seem to have laid the groundwork for more explicit governance in the supply chain under consideration. In the following, we discuss the implications of our findings and analysis for MT-SSCM in general.

6. Discussion

The case study provided numerous findings that are particularly interesting for MT-(S)SCM in a number of ways. The TfS model of Garcia-Torres et al. [24] was found to generally apply, insofar as the initial goal to *trace* the origin of the raw materials in an FC's products resulted in cyclical (iterative) improvements, including improved and increased collaboration among supply chain actors and the beginnings of governance of the MT-SC (recall Figure 1). However, the focus at the core of this research was the question of what barriers there are to achieving transparency in MT-SSCM, and how this could be operationalised, so that FCs may achieve transparency to enable such tracking and tracing, governance and collaboration in the future. In this discussionn we analyse the relevant findings from our case study that demonstrate how *transparency* (in place of column "traceability" in the original TfS framework, recall Figure 3) can be operationalised, before pointing to the limitations of our research and making suggestions about areas for further research.

Analogous to our findings, we structure our discussion of primary findings and their relevance for MT-SSCM into the following categories: underestimated complexity (6.1); distance of Tier-1 suppliers to their upstream SC (6.2); MT-SC collaboration and governance (6.3); the iterative nature of obtaining transparency (6.4); and the temporal nature of supply chain mapping (6.5).

6.1. Underestimated Complexity

The case study demonstrates that sub-supply chains can potentially be significantly more complex than companies assume. Considering that the SC maps depicted in Figures 4 and 6 are only for the SC of one supplier supplying specific products to one FC, it is plausible that the entire cobalt supply chain is even more complex. It follows, that increasingly demanding or critical stakeholder expectations [15] will not change the fact that, at present, potentially many raw material supply chains are surprisingly more complex, and that this only becomes apparent, once they are systematically explored [83]. Furthermoren this underestimated, or at least unknown, complexity could pose a threat to FCs' and downstream suppliers' risk management, as it would mean that they do not have accurate or enough information to base risk management estimates on [31].

However, not only is the increased MT-SC complexity worth noting, but also how unexpected this was. Neither the T1S nor FC1 had anticipated an almost threefold increase in the number of sub-supply chain actors. Both practitioners and academics should take this into account when addressing complex SC. Undertaking MT-(S)SCM is more manageable when considering a supply chain with a total of approximately 30 actors. If this number significantly increases, i.e., to 80 (or higher), the amount of coordination, communication and risk management required can quickly become overwhelming. Thus, MT-SSCM research and frameworks should account for such eventualities. This underestimated (or unanticipated) complexity should not serve as a reason to not aim for SC transparency but should

be recognised and calculated in terms of managing expectations. One conclusion that can be drawn from our findings, in this regard, is that FCs should aim for sub-SC rationalisation in order to reduce complexity and the corresponding sustainability risk. Finally, this research lends weight to the concept of proactive supply chain leadership, in order to improve SSCM performance [81].

6.2. Distance of Tier-1 Suppliers to their Upstream Supply Chain

This case study clearly showed that automotive (but also electronic) mineral supply chains are different from agricultural/produce/food and apparel supply chains. In earlier studies of MT-(S)SCM (e.g., [22,29,30,73]), the supply chain was conceived of as consisting of three tiers. In the SC maps depicted in our case study, we solely depict extraction, treatment, production, and processing steps. If we were to add transport/logistics service providers, there would be even more steps. Our case demonstrates that supply chain actors at the same tier level have business relations, meaning that sometimes transactions can occur at the same tier level. Hence, unsurprisingly, Tier-1 suppliers (often large multinational companies themselves) in such supply chains are far removed from the realities of mid-stream and upstream SCs and are correspondingly under-informed about the structure of the sub-supply chain. In this manner, they are forced to rely on the disclosure of their suppliers (Tier-2+) and thus it can be highly problematic for FCs purely relying on their Tier-1 for supply chain transparency. Such incomplete SC disclosure does not have to be deliberate, but could also be due to a lack of available knowledge and internal resources to improve the knowledge at T1S. On the other hand, previous research has pointed to the special "double role" of Tier-1 suppliers [33] and that such suppliers' compliance with the sustainability goals and expectations of FCs can depend on public attention and pressure on Tier-1 and the perceived risks of inactivity or non-compliance [26,27]. We argue that our research demonstrates how such mapping projects can significantly increase attention within Tier-1 suppliers' organisations for the need for more resources to address the topic of MT-SC transparency for SSCM. On the other hand, Tier-1 suppliers usually sign contracts in which they agree to adhere to FCs' code of conduct and enforce these further up the supply chain. Such transparency exercises could be seen as risky for Tier-1 suppliers, as it exposures their lack of knowledge.

6.3. Multi-Tier Supply Chain Collaboration & Governance

Whilst the focus of this research has been on the transparency/traceability part of the TfS framework (rather than collaboration and governance), it became clear, as the framework suggests, how interconnected these three aspects [24,25] are (recall Figures 1 and 3). In the case at hand, the ability to co-conduct transparency and SC mapping resulted from a string of sustainability workshops and thus we can surmise that, without enough collaboration, a full supply chain transparency project does not have a high chance of success. The engagement, whilst often treated cautiously to begin with (which is an understandable reaction to being audited), in some cases was then used as a platform for more exchange between the mid- and up-stream sub-suppliers and T1S and/or FC1. Potentially, the direction of such a transparency push must not necessarily go from downstream FCs back up to the raw material but could, (conceivably) begin with mines/raw materials producers, who, together with treatment units, wish to work for more transparency in their downstream SC [45,53]. This might then also lead to more exchange, collaboration and eventually strengthened governance [41]. In many cases, the usefulness of achieving MT-SC transparency, undertaking due diligence for responsible sourcing and trying to improve sustainability through the supply chain was able to be "sold" as a benefit for all participating SC actors as it reduces their risks and positively differentiates them, making them a more attractive (sub-) supplier in the future. Finally, engaging third-party, subject matter experts, in the form of service providers or relevant organisations (e.g., international bodies, NGOs), with specific SC expertise, and who have no buyer-seller relation to the product at hand, is potentially a significant factor that lends legitimacy to the undertaking. Such third-parties can interact with auditees in a different manner to the FC or downstream direct/Tier-1 suppliers. We argue that companies attempting to undertake such supply chain mapping audits themselves will struggle due to the lack of resources

and, specifically, expertise in terms of the sub-supply chain mapping process and because their role as a buyer adds pressure to achieve and declare biased outcomes.

6.4. Iterative Nature of Gaining Transparency in MT-SCs

Our case study demonstrates that SC transparency is not a static state, but rather something that needs to be worked towards. Thus, operationalising supply chain transparency in large, multi-national SCs probably requires an iterative process, which corresponds to the self-reinforcing cycle proposed by Garcia-Torres et al. [24]. One begins with an incomplete picture (an initial estimated supply chain map), that nonetheless provides a frame of reference and seeks to improve MT-SC visibility [31]. Gong et al. [84] remind us that MT-SSCM should be thought of in terms of processes. They see SC mapping as the first step in such a process toward the dissemination of sustainability throughout the MT-SC. This process could be done at product level, supplier level or perhaps for a raw material. Once mapping activities reveal new supply chain actors, these need to be included in the mapping process and integrated. We argue that proposing a traceability system before having conducted intensive mapping activities will be limited because such an SC map will most probably be incomplete and thus important parts of the supply chain could be missed in the tracking/tracing system. This problem would be intensified if there is not sufficient trust that (sub-) suppliers will proactively disclose that other materials, products or parts are entering the SC but that such sources are not currently in the tracing system. Thus, our case study findings suggest that tracking and tracing would first require multiple iterations of SC transparency and mapping undertakings before it can be effective.

6.5. Temporal Nature of Supply Chain Mapping

One final major finding of the case study was the reminder that supply chains are temporal by nature, and that particularly further up the supply chain, sub-suppliers can change their sources without Tier-1 suppliers or FCs knowing. Moreover, new sources/sub-suppliers can be introduced after such SC mapping audits have taken place, rendering the supply chain map incomplete and the validity limited to a certain point in time. This necessitates re-audits to confirm if sub-suppliers have in fact been discontinued/removed from the supply chain and if new actors are now contributing to the SC. Increasingly technological solutions (such as blockchain) are emerging that could support high levels of complexity and enable real-time confirmation of SC material flows [112,113]. Such solutions would register discontinuation of certain sub-suppliers but new SC actors would have to be brought onboard. Nonetheless, supply chain mapping audits provide an effective method to understand the real structure of a supply chain at a point in time, which can then serve as a base for further activities and measures that enable real-time tracking and tracing. At present, to our knowledge, no technological solutions can also confirm the trustworthiness of the data entering the system, which means that audits are required to validate the SC sustainability data.

Finally, it is worth considering that attaining MT-SC transparency can be independent of sustainability objectives. However, currently, companies seem much more likely to collaborate on sustainability issues. Achieving more SC transparency could also open up an FC to a lot more risks, indirect impacts that are discovered and increased sub-supply chain responsibilities. Given the reputational risk associated with gaining transparency (knowing what is there) without having the resources to back up the process with SSCM (doing something about it), it is not entirely surprising that MT-SC transparency is not so widespread in such critical supply chains. Recognising the tendency to opacity, the researchers are grateful to FC1, T1S and ASPC1 for allowing such project insights to be subject to academic inquiry.

7. Conclusions

Progress in achieving SC *Transparency for Sustainability* must be made so that, just as eventually SSCM should become the norm in SCM [10], MT-SSCM should become the norm in SSCM. In this paper, we find evidence for the idea that SC transparency is the pre-requisite for all proceeding MT-SC

sustainability activities (whether understanding human rights risks and impacts, working conditions or environmental performance in the sub-supply chain). Our research builds on the framework of traceability for sustainability, uncovering challenges to obtaining transparency and demonstrating how transparency can be operationalised by focal companies. Obtaining transparency can begin an enabling cycle that can improve traceability of products, parts and raw materials, contributing to better collaboration throughout the supply chain and improved SC governance. However, we found that in certain complex supply chains, the process is a lot more complex than implied in the extant literature. By analysing an in-depth case involving MT-SC transparency, we identify potential factors that require more attention when considering the operationalisation of transparency for sustainability in MT-SSCM.

7.1. Implications of Our Research

This research provides much needed empirical insights to academics writing on MT-SSCM approaches, frameworks and models. By demonstrating the unexpected complexity in an exemplary raw material SC, this should cause theoreticians to consider the complex reality that is not accounted for in dyadic or triadic, orderly conceptions of supply chains. Furthermore, whilst this research concerned itself with cobalt, authors have pointed out that various mineral SCs demonstrate similar characteristics [41]. We hope to contribute to a debate around transparency vs. traceability that needs to be better understood in terms of ordering/hierarchies. Technological advancement coupled with the pressure on FCs to demonstrate transparency in their MT-SCs is leading to increasing activities and a number of (pilot-)projects tracking/tracing materials and aiming for SC transparency. We concur with previous authors that such transparency activities contribute to improvements in other areas of SCM and our case study findings provide evidence for this.

For practitioners, our case study demonstrates the importance of FCs of being proactive and taking leadership to begin working towards MT transparency in the most critical SCs for improved SSCM. The research showed that SC complexity is underestimated and that this could have serious consequences for an FC's risk and reputation management. On the other hand, once such activities have been led by the FC, there can be positive reinforcing side-effects in terms of strengthening trust, collaboration and governance with strategic suppliers.

7.2. Limitations

There are a number of limitations to the approach taken to SC transparency and to the research itself. The SC mapping audits were announced in advance, as contractually agreed upon. This approach is in contrast to some general supplier sustainability audits, which are unannounced and focus on the current state of sustainability at factory/supplier premises. The audits examined for this research were primarily concerned with due diligence mechanisms, responsible sourcing management systems and suppliers' SC mapping capabilities to generate upstream SC knowledge. Thus, contrary to a supplier sustainability audit, whereby underage workers can be removed from premises or fire extinguishers placed throughout the premise on audit day, such processes, responsibilities, mechanisms and systems cannot be easily "faked" even with some advance warning. There was a high degree of reliance on the quality of the auditing undertaken. Thus, one of our researchers participated in an audit of one of the T1S facilities and accompanied ASPC1 throughout the entire audit process. In this manner, we could be sure that uncomfortable questions were being asked, that spot checks were conducted and that ASPC1 checked the capacity of the (sub-)supplier to know their sub-supply chain and implement due diligence on their raw material sourcing.

As with all single-case case-study research, we are aware of the limitations to the generalisability of our findings. We selected this particular raw material SC transparency project as cobalt represents a particularly difficult, opaque and critical market. Our survey of the literature found no examples of MT-SSCM being documented and explained at the level of operationalisation for such a complex supply chain and in the automotive industry. Thus, given the opportunity to participate in this case study, we accepted the limited scope (one focal company, one tier one supplier) and the lack of cross-case

comparisons. Whilst much more information was gathered as part of the project, in the interest of fair anonymisation, our research primarily focused on the extent of supply chain visibility achieved (and not, e.g., the performance of (sub-)suppliers regarding due diligence).

7.3. Recommendations for Further Research

As MT-(S)SCM is still a relatively new field of research, there are many options for building on the concept of transparency/traceability for sustainability. We commend the foundational work of Garcia-Torres et al. [24] and see the descriptive and explanatory potential of the model, particularly in that it proposes an enabling cycle, whereby the aspects traceability, collaboration and governance contribute to one another and depend on each other. We have attempted to shine a light on the workings of traceability within this model (preferring the term transparency) and demonstrate how such transparency might be operationalised and what challenges FCs may face in operationalising TfS. Further research could look at other aspects of the theoretical model to determine whether empirical/real-world experiences align with it. Particularly once more (focal) companies have begun to map entire supply chains and or industry cooperation leads to better integrated technological solutions to improve transparency in MT-SCs, then research could look at the generalisability of our findings and continue to learn from different types of industries and supply chains. Another potential field for future research could be at the intersection of SC sustainability risk management and transparency in MT-SSCM. As argued above, increased MT-SC transparency should lead to better and more realistic data about more probable and accurate risks, so that companies can advance to pre-empting likely risks in the sub-supply chain before they eventuate. Finally, different auditing standards and approaches for achieving transparency could be the subject of further inquiry, to better understand their effectiveness and role in MT-SSCM as a tool and process.

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